

# Platinum as a release layer for thermally formed optics for IXO

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## ABSTRACT

Platinum is being explored as an alternative to the sprayed boron nitride mandrel release coating under study at GSFC for the International X-ray Observatory<sup>1</sup> (IXO). Two and three inch diameter, polished (PFS) and superpolished (SPFS) fused silica flat mandrels, were used for these tests. Pt was applied to the mandrels by DC magnetron sputtering. The substrate material was 400 micron thick D263 glass, the material which has been proposed for the IXO segmented optics. These substrates were placed on the mandrels and thermally cycled with the same thermal profile being used at GSFC in the development of the BN slumping for IXO. After the thermal cycle was complete, the D263 substrates were removed; new D263 substrates were placed on the mandrels and the process was repeated. Four thermal cycles have been completed to date. After initially coating the mandrels with Pt, no further conditioning was applied to the mandrels before or during the thermal cycles. The microroughness of the mandrels and of the D263 substrates was measured before and after thermal cycling. Atomic force microscopy (AFM) and 8 keV X-ray reflectivity data are presented.

**Keywords:** X-ray telescopes, thermal slumping, release agents, microroughness, platinum deposition

## 1. INTRODUCTION

### 1.1 Replicated segmented substrates for X-ray telescopes

The large size and low mass to area ratio of the grazing incidence telescope of the International X-Ray Observatory (IXO) require that its cylindrical mirror shells be very thin. Therefore by necessity they have to be segmented. A mirror shell at a given radius is composed of several segments with an identical figure. In fact both the parabolic and hyperbolic sections of the outermost mirror shell of IXO, which has an outer diameter of about 3.2 m would be divided into twenty-four segments. Consequently replication from a mandrel with the inverse figure is an appropriate method of applying the desired figure to the telescope mirror segments. One of the methods under study is thermal slumping of glass upon a mandrel made of a material with a higher melting point than the glass.<sup>2,3</sup> A thin, lightweight type of glass under study at several research centers is "D263", a commercial product of Schott AG. The surface roughness of this glass is low so its X-ray reflection efficiency is close to the theoretical value.

One of the issues in thermal slumping is separating the replica from the mandrel after the thermal forming is complete. The 400 micron thick replica has to be removed with minimal force to avoid shattering. A thin release coating is applied to the mandrel to facilitate release of the replica after the thermal forming process is complete. This release coating has to be smooth and must allow the substrate to conform to the figure of the mandrel. We consider a process where the separation layer is deposited upon the mandrel. Ideally, the separation agent would not only preserve the low surface roughness of the glass through the thermal cycle, it would also enable optical metrology to be performed on the mandrel and remain on the mandrel so that the process can be repeated for the fabrication of additional replicas from the same mandrel. The replicas would then have to be coated with a material that has high X-ray reflectivity such as iridium or platinum.

### 1.2 The objectives of this study.

Two mandrels participated in this study. One was a 5 cm diameter superpolished fused silica flat with a surface roughness of 2 Å and the other was a 7.5 cm diameter polished fused silica flat whose surface roughness was 11 Å. The

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initial surface roughness of the D263 replica material was approximately 2 Å. Our objective was to determine how the difference in the surface roughness of the two mandrels influences the surface roughness of the D263 replicas after they experience the thermal cycle. The goals of this study were to determine if a sputtered coating of platinum on the mandrel will:

- facilitate the release of D263 glass from the mandrel
- leave the excellent surface roughness of the D263 glass unchanged
- allow multiple replication procedures without any reconditioning of the Pt coating

Because both the mandrels and the D263 glass were flats we were not able to determine how accurately the replica conforms to the inverse figure of the mandrel following the thermal cycle. This is part of our on-going study.

### 1.3 Platinum coating as a release agent

The release agent of our studies was a 40 nm layer of platinum that was deposited at CfA by DC magnetron sputtering. The base pressure of the system prior to introducing argon into the chamber was  $2 \times 10^{-7}$  torr. During the deposition the working pressure was 3.2 mtorr of argon.

Platinum has the following favorable qualities.

- the coating process is deterministic, the same coating can be applied to any mandrel
- its optical reflectivity enables optical metrology of the mandrel
- the deposition process can be easily duplicated in any DC magnetron coating facility

## 2. RESULTS

### 2.1 The thermal cycle

The thermal cycle that the mandrel plus substrate pairs experienced is shown in Figure 1. It is the same as the temperature profile being used at the Goddard Space Flight Center in their BN assisted separation procedures for IXO.

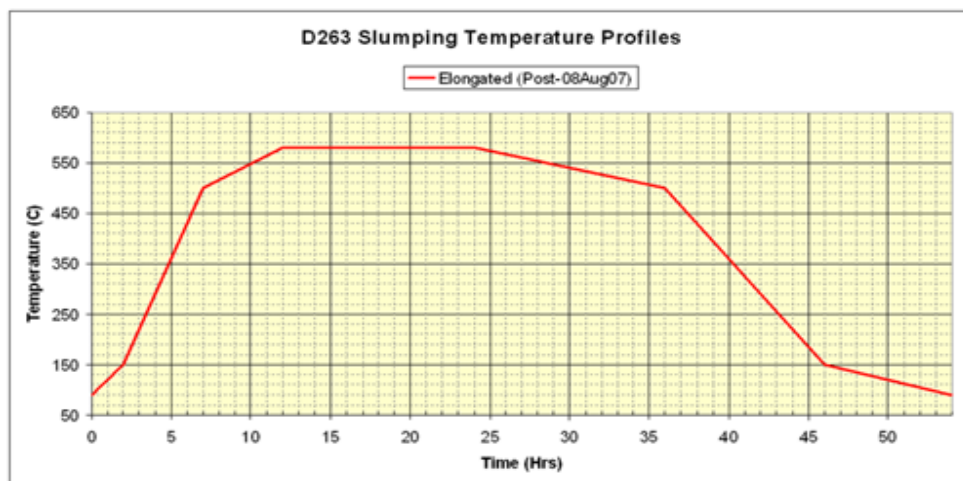


Figure 1. The temperature profile within the oven containing the mandrel and replica.

The total time of the thermal cycle was 54 hours. The maximum temperature reached was 580 C where it was held for 12 hours. The time that it took to attain that temperature was 12 hours. At this temperature-time profile the D263 glass is

expected to slump and conform to the figure of the mandrel as it does in the GSFC tests. The mandrel plus sample were allowed to cool down more slowly over a period of 30 hours.

### 2.2 Measurements

Three D263 flats were thermally cycled with the platinum coated super-polished mandrels (SPFS) and four flats with the ordinary polished (PFS) mandrels. We determined the microroughness of both mandrels before and after all the slumping procedures by measuring their 8 keV X-ray reflectivity as a function of angle. The relation between the X-ray reflectivity as a function of angle and the surface roughness was determined using the IMD model developed by Windt<sup>4</sup> that is used with the IDL software system. The reflectivity of the Pt coated mandrels before and after all the thermal cycles they experienced is shown in Figure 2.

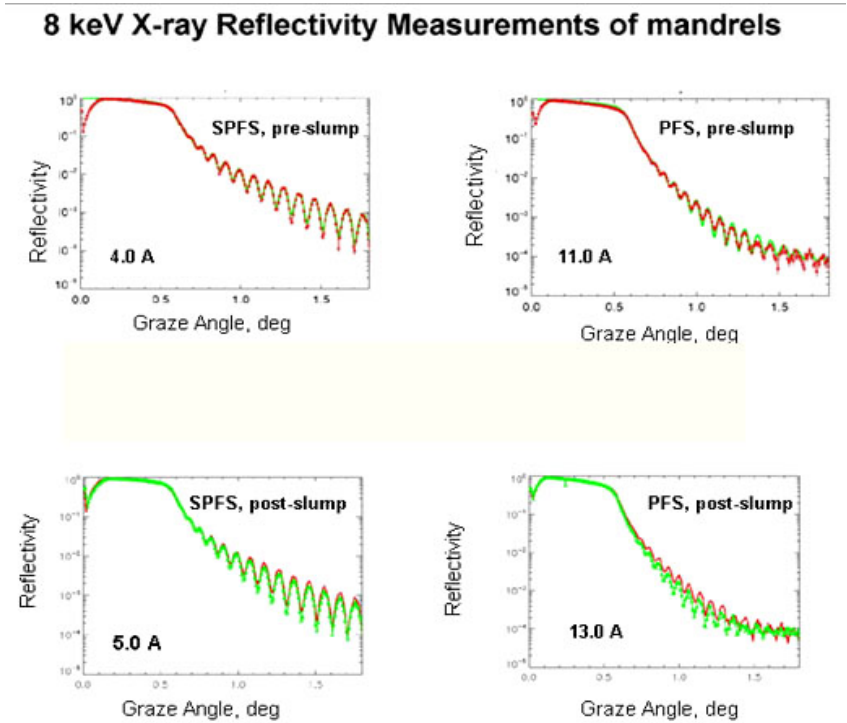


Figure 2. X-ray reflectivity of the polished and superpolished Pt coated mandrels is shown prior to and after all the thermal cycles. Surface roughness as determined by the Windt IMD model<sup>4</sup> is indicated in the lower left section of each of the four panels. In a color display the top panels contain two curves, the model is green and the data is red; in the bottom panels the pre-thermal cycle data is in red; the post cycle, green. (When seen in black and white it is difficult to distinguish between the two curves.)

The surface roughness of the mandrels following each cycle is listed in Table 1.

Table 1. Surface roughness of the superpolished (SPFS) and polished (PFS) mandrels pre and post thermal cycles

	Pre-Slump (Ang.)	Post 1 (Ang.)	Post 2 (Ang)	Post 3 (Ang.)	Post 4 (Ang.)
SPFS	4.0	5.0	5.0	5.0	N/A
PFS	11	12	12	13	13

The X-ray reflectivity measurements indicate that the Pt coated mandrel experienced a small increase in roughness after thermal cycling. However, the effect of the change is insignificant in light of the results of measuring the surface roughness of the replicas as described below.

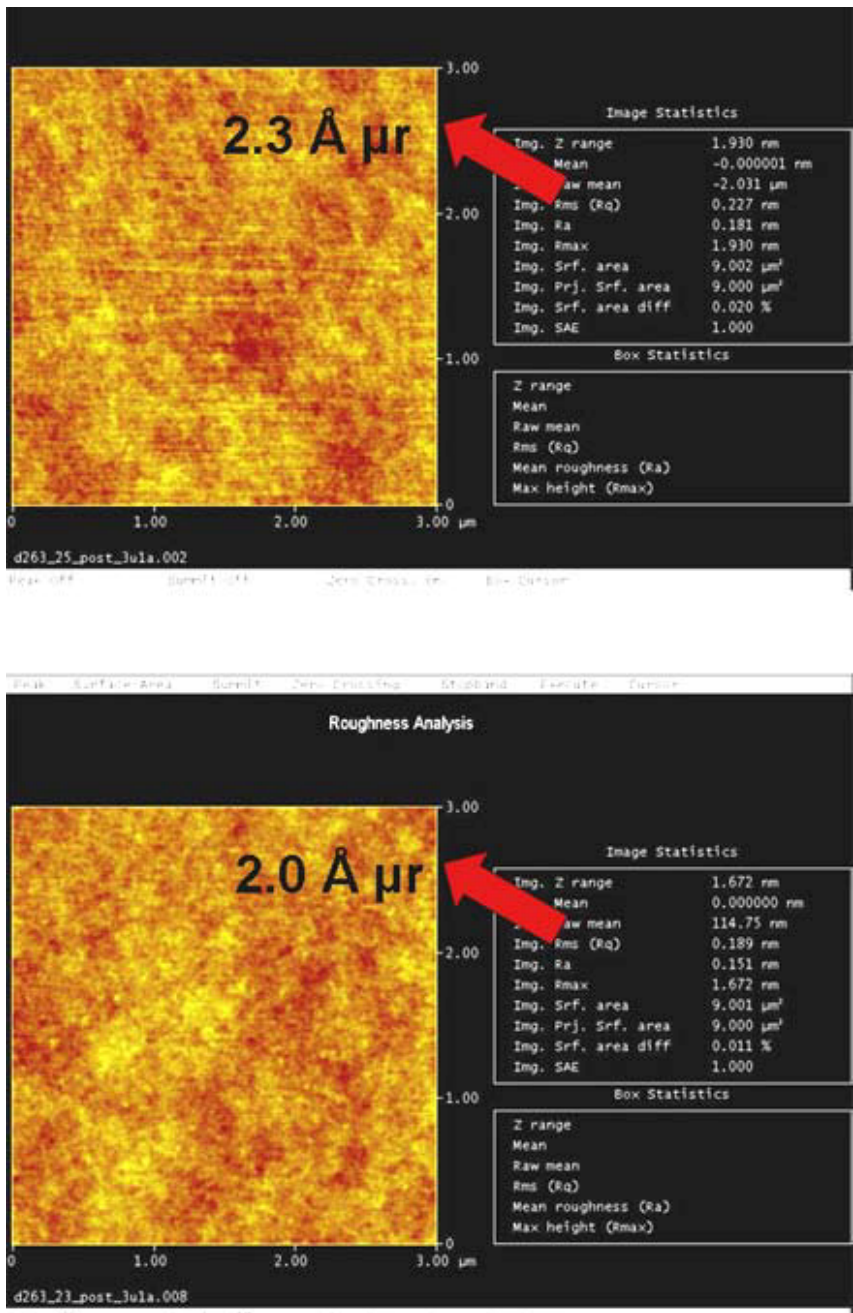


Figure 3. Scans of two replicas with an atomic force microscope over lengths of 3 microns.. The top panel is a flat that was thermally cycled in contact with the SPFS mandrel, the bottom panel, with the PFS. The red arrows point to the measurements of their surface roughness, which are similar despite the difference in the roughness of the mandrels.

The condition of the thermally cycled D263 glass is shown in Fig. 3, which are the 3 micron scan images obtained with an atomic force microscope. The most notable result is that the roughness of the thermally cycled D263 flats is the same for both the superpolished and polished mandrels even though the difference in the mandrel's roughness is substantial.

### 3. SUMMARY OF RESULTS AND FUTURE WORK

#### 3.1 Summary

We can conclude the following from our measurements:

A 400 Angstrom coating of Pt allows easy release of D263 from the mandrel when the two are thermally cycled in direct contact with the same temperature-time profile used in slumping tests at GSFC for IXO.

The thermal cycle used does not change the surface roughness of bare D263.

At least two flat D263 substrates can be thermally cycled on the same mandrel without changes in their surface roughness; measurements on the remaining substrates have not yet been completed.

With D263 flats in direct contact, the surface roughness of the Pt coated flat mandrel increases only slightly if at all after experiencing four thermal cycles.

The post thermal cycle roughness of the D263 flats does not depend on the surface roughness of the coated mandrel. Results are similar with both the polished (11 Ang. rms) and the superpolished (4 Ang. rms) mandrels.

Many lightweight figured replicas can be coated simultaneously in a large DC magnetron sputtering facility with the reflective material, eg Ir or Pt.

#### 3.2 Future Work

The next step would be to repeat these tests with mandrels that have the actual figure of an IXO substrate. Utilizing larger mandrels would be desirable. If similar results are obtained with figured mandrels where the D263 actually slumps to the mandrel with the Pt coating remaining on the mandrel then this may be the separation method of choice for IXO.

To date we have completed measurements of the D263 substrates from the first and second thermal cycles. We have yet to complete the measurements of the remaining two sets of substrates; and we intend to continue the process to understand how many thermal cycles can be completed without re-conditioning of the mandrel.

### 4. ACKNOWLEDGMENTS

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### REFERENCES

- [1] Bookbinder, J.A., "An Overview of the International X-ray Observatory (IXO)", Proc. SPIE 7732, (Paper 7732-46, this symposium) (2010)
- [2] W.W. Zhang, M. Atanassova, M. Biskach, P.N. Blake, G. Byron, K.W. Chan<sup>1</sup>, T. Evans, C. Fleetwood, M. Hill, M. Hong, L. Jalota<sup>1</sup>, L. Kolos, J.M. Mazzarella, R. McClelland, L. Olsen, R. Petre, D. Robinson, T.T. Saha, M. Sharpe, M.V. Gubarev, W.D. Jones, T. Kester, S.L. O'Dell, D. Caldwell, W. Davis, M. Freeman, W. Podgorski, P.B. Reid, and S. Romaine, "Mirror technology development for the International X-ray Observatory mission (IXO)" Proc. SPIE 7732, (Paper 7732-51, this symposium) (2010)

- [3] Canestrari, R., M. Ghigo, G. Pareschi, S. Basso, and G. Motta, "Techniques for the manufacturing of stiff and lightweight optical mirror panels based on slumping of glass sheets: concepts and results" SPIE. 7437, 743711 (2009)
- [4] Windt D., "<http://www.rxolc.com/idl/>"